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DEVICE FOR PERSONAL IDENTIFICATION

This invention relates to a device for personal identification by means of at least one fingerprint

- with at least one light source for illuminating and/or transilluminating the forward area of a finger by means of light pulses and
- with at least one fiber optic finger resting surface for taking an optical picture of the fingerprint, by which surface the optical image can be transported to at least one sensor unit in which the optical image can be converted into electrical signals,

at least one light source being located laterally next to the finger resting surface and the light from the light source can be radiated in the direction to the side of the finger resting surface which is intended for resting the forward area of the finger and which faces away from the sensor unit.

These devices are used to record and process fingerprints and can be used anywhere personal identification is necessary.

For example, in this connection the areas of computer engineering, entry systems, criminal science, medicine, protective systems in general and the banking and financial sector can be named.

At this point, in the field of devices for personal identification by means of at least one fingerprint, systems are known (compare international patent disclosure document WO 98/27509) which have a light source which is located over the finger to be transilluminated so that the finger, when placed on the finger resting surface, is located between the light source and finger resting surface. The light radiated by the light source after passing through the forward area of the finger and after recording information with respect to the fingerprint travels through the fibers of the finger resting surface into the sensor unit which is located underneath the finger resting surface and is then analyzed by means of an evaluation unit which is located downstream of the sensor unit.

But in connection with this so-called direct-optical process it has been exceptionally problematical that the individual to be identified by means of his fingerprint to a certain extent must insert the pertinent

finger into a cavity or an opening between the light source and the finger resting surface.

This is extremely unfavorable in psychological terms and significantly increases the hesitation threshold for using a generic device, as experience shows, because the individual who is to be identified is so to speak required to insert an exposed body part in the form of the forward area of his finger into a cavity which he cannot visually inspect, which is often accompanied by a increased feeling of anxiety.

The aforementioned problem of psychological overcoming does not exist in a generic device for input of irregular patterns (compare German patent disclosure document DE 44 04 918 A1). This device contains a bundle of optical fibers, on the two ends of which one entry surface and one exit surface at a time are formed. An illumination device delivers irradiation light such that a light pattern is formed according to the convex part of the object in contact with the entry surface and according to the concave part of the object out of contact with the entry surface, If an angle of incidence of the irradiation light is set which is greater than the critical angle on the boundary surface between the core part of one optical fiber of the bundle of optical fibers and the air, it is possible to achieve total reflection on the entry surface out of contact with the concave part of the object and not to achieve total reflection on the entry surface in contact with the convex part of the object; this yields reflection light with a light pattern which corresponds to the irregular pattern. The resulting light pattern is input via the exit surface into a photoelectric converter device and is converted by it into electrical information.

The device known from DE 44 04 918 A1 is however disadvantageous in that it works with light of constant intensity and is based on the principle of disrupted total reflection. In this way both the type of illumination and also the light guidance become rigid and inflexible, since at an illuminance of the ambient light of more than roughly 3000 lux the photoelectric converter device is quickly oversaturated so that reliable results can no longer be achieved with the conventional device.

Proceeding from the above described disadvantages and insufficiencies, the object of this invention is to develop a generic device for personal identification in a way which enables illumination of the forward area of the finger which leads to sufficient, reliable results, in which furthermore it is possible to look completely into the device for personal identification and also the process of personal identification is transparent and reproducible for the individual to be identified, and with which finally constantly good

and reliable results can always be achieved regardless of the respective ambient light conditions.

This object is achieved in a device as claimed in the preamble of the main claim in that according to the teaching of this invention the duration and/or the intensity of the light pulses emitted by at least one light source can be controlled depending on the ambient light conditions.

Therefore, in a manner which cannot be foreseen for one skilled in the art, adaptive light control (ALC), i.e. a type of "intelligent light control", is made available, by which the deficiencies of changing ambient light conditions, as for example changing room illumination or changing incident solar radiation, can be compensated by the device as claimed in this invention or the algorithm which controls the device being adapted to the respective light conditions.

In the device as claimed in the invention, to do this there is preferably at least one control means for controlling the duration and/or the intensity of the light pulses. With this control means a continuous or temporary measurement process can be carried out, with which permanently good picture quality can be determined and with which if necessary optimum saturation which is matched to the contrast and depth of focus can be achieved by means of brief light pulses, the brief light pulses in their duration and/or in their intensity being metered exactly to the actually required amount of light.

According to one advantageous development of this invention the control means has:

- at least one acquisition module for acquisition of the ambient light conditions, and the acquisition module can be made integrally with the sensor unit and/or as part of the sensor unit;
- at least one evaluation module for determining the duration and/or the intensity of the light pulses matched to the ambient light conditions acquired by the acquisition module, and the evaluation module can be made integrally with at least one evaluation unit and/or as part of at least one evaluation unit which is located preferably downstream of the sensor unit; and
- at least one storage module for storing threshold values which have been determined for controlling the duration and/or the intensity of the light pulses, and the storage module can be made integrally with at least one storage unit and/or as part of at least one storage unit which is located preferably downstream of the sensor unit.

The manner of operation and the function of the control means are for example such that the

acquisition module acquires the respective ambient light conditions, they are analyzed and evaluated in the evaluation module and comparison with the stipulated threshold values which have been stored in the storage module takes place in the evaluation module.

Depending on the result of this comparison, then the light source, which is connected to the control means and here especially to the evaluation module, is operated by the control means, the duration and/or the intensity of the light pulses which have been emitted by the light source being adapted to the determined ambient light conditions.

In this way, the light pulses can be made dynamic and adaptive both in their duration and also in their intensity in order to make available for any type of ambient light (for example, strong incident solar radiation, weak incident solar radiation, dimmed light, diffuse light, gas light, moonlight, artificial illumination...) the required incident light radiation and moreover to obtain a high-contrast and defined picture of the fingerprint.

In particular, with adaptive light control illuminances of zero lux to roughly 40,000 lux can be accomplished, the latter illuminance value corresponding roughly to direct incident solar radiation. The results which can be achieved with this adaptive light control, compared to conventional illumination systems with continuous light, have an increase in contrast depth and depth of focus by up to roughly eighty percent, the type of light control as claimed in the invention having the advantage that under changing illumination conditions it makes available and can meter the required amount of light in a time interval of less than one hundred milliseconds so that under all conceivable light conditions an almost uniform picture quality can be achieved.

Therefore, the advantage of this device as claimed in the invention can be seen in the "intelligent triggering" which if necessary adjusts the incident amount of light to a certain extent itself and makes it available and computes it around the object to be illuminated, i.e. around the forward area of a finger, for each region separately, so that overexposure or underexposure is precluded with a probability which borders on certainty.

In this connection constant illumination units, as are provided for example in conventional devices for personal identification by means of at least one fingerprint, result in the further disadvantage that the

amount of light which is made available by them cannot be delivered as referenced to the object, i.e. an object which is ten millimeters thick is illuminated with the same amount of light as an object which is five millimeters thick, from which blurriness and also partial overexposures result.

In contrast, this invention enables uniform illumination of an object, for example the forward area of the finger, regardless of the thickness of the object which otherwise can have more or less strong light conductivity or a more or less strong light reflectivity, and regardless of whether this object is illuminated frontally, laterally, and/or on the back side by stray light. Accordingly in this invention it is irrelevant at what angle and from where light is radiated onto the object to be illuminated; only the duration and/or the intensity of the additionally required light need be controlled individually for each region.

The advantages of this adaptive light control ultimately lead to the fact that a finger image can be determined without significantly changing the exposure times while maintaining contrast and depth of focus to the full extent.

Feasibly, the control means for adaptive light control is made as at least one logic component and/or as at least one logic circuit, especially as at least one standard logic component and as at least programmable logic (FPGA = field programmable gate array). Alternatively or in addition, the control means can also be made as at least one digital signal processor (DSP) and/or as at least one microcontroller.

As already cited above, the control means which is intended for implementing adaptive light control according to one embodiment of the invention has at least one acquisition module, at least one evaluation module, and at least one storage module. If at this point the acquisition module is preferably made integrally with the sensor unit and/or as part of the sensor unit, the photosensitive surface and/or the photosensitive layer of the sensor unit can request the required amount of light by means of adaptive light control to a certain extent itself, and for each of its regions; this works especially preferably when the evaluation module of the control means is made integrally with the evaluation unit and/or as part of the evaluation unit.

Conventional devices for personal identification by means of at least one fingerprint cannot do this because these known devices, if at all, can only control the incidently radiated light for the entire

region of the sensor unit inflexibly and rigidly; in contrast, only adaptive light control is able to compute and immediately deliver, for each region of the surface and/or the layer of the sensor unit, the amount of light which is necessary in view of the ambient light conditions with respect to duration and/or with respect to intensity in the evaluation module with regard to the optimum saturation.

According to one especially advantageous development of this invention it can be part of the adaptive light control (ALC), i.e. "intelligent light control", to make the amplification of the electrical signals in the sensor unit and/or in the evaluation unit variable over the different regions of the optical image.

The background of this especially advantageous development is the fact that the intensity distribution and accordingly the contrast of the light which has been scattered within the forward area of the finger is neither uniform nor constant over the entire width of the optical picture, but is less in the middle regions of the optical image than in its edge regions; this among others is associated with the fact that there is at least one light source laterally next to the finger resting surface and that the light from the light source can be radiated in the direction to the side of the finger resting surface which is intended for placing the forward area of the finger and which faces away from the sensor unit. In this way less light travels into the central regions which are covered by the forward region of the finger on the side of the finger resting surface facing away from the sensor unit than into the side regions so that the intensity and, in direct proportion thereto, the contrast of the scattered light in the central regions is weaker than in the side regions.

To eliminate this defect, according to one preferred development of this invention the amplification of the electrical signals in the middle regions of the optical picture can be greater and in this case greater for example by a factor of 2 to 3 than the amplification of the electrical signals in the edge regions of the optical image. This electronic modulation by means of variable amplifications can be done in each line of the optical image.

In this way, in an elegant, electronically implemented manner it is possible to compensate for the fact that the intensity and the contrast of the scattered light in the central regions is weaker than in the side regions, and the amplification can be selectively chosen over the different regions of the optical picture such that the output signal which is directly proportional to the product of the respective scattered

light intensity/contrast and the respective gain is of rather constant intensity; this technical measure makes it possible to significantly improve the quality of the results which can be achieved with this device.

According to one inventive development of this device it is designed for passage into a neutral state. This is for example advantageous within the framework of using this device in mobile phones or in motor vehicle parts, for example in steering wheels, in operating knobs or in door locks, since in these applications the electrical voltage necessary for operating the device is supplied generally from batteries, optionally in addition also using solar collectors so that savings potentials in this regard by providing a neutral state of the device are very welcome.

To do this, feasibly there can be at least one capacitive circuit which is preferably integrated into the control means, by which circuit the device after a stipulated interval of non-use passes into the neutral state (= so-called "sleep" mode) and by means of which the device is re-"awakened" when the forward area of the finger is placed on the finger resting surface, i.e. passes again into a ready-to-operate state; viewed in this way, in this device for personal identification both a sleep function and also a wake-up function can be implemented.

As already indicated above, at least one light source in adaptive light control performs an important function within the framework of this invention. Here it must be considered that for purposes of uniform illumination of the forward area of the finger, in most practical applications there is more than one light source, for example two light sources or especially four light sources which can be arranged symmetrically to one another and/or which can be arranged distributed laterally or annularly, here especially essentially uniformly, around the finger resting surface.

According to one especially inventive development of this device the respective duration and/or the respective intensity of the light pulses emitted by the respective light source can be selectively controlled as matched to the ambient light conditions; this means in other words that the respective duration and/or the respective intensity of the light pulses emitted by the individual light sources can be controlled independently of one another, in this case especially depending on given threshold values. Therefore all light sources can be triggered independently of one another, the respective duration and/or the respective intensity being computed preferably individually in the evaluation module for each light

source.

Not only triggering of light sources and the number of light sources, but also their arrangement in this invention play an inventive role. By the light source being located laterally next to the finger resting surface and by the fact that the light can be radiated from the light source in the direction to the side of the finger resting surface which is intended for resting the forward area of the finger and which faces away from the sensor unit, illumination of the forward area of the finger which results in adequate, reliable results is enabled.

In this case light incidence on the forward area of the finger takes place essentially from the side, at least part of the light penetrating into the interior of the forward area of the finger and being scattered there, scattering taking place essentially into all directions, thus among others also in the direction of the fiber optic finger resting surface; therefore this invention is based to a certain extent on transmitted light technology, i.e. the optical picture of the fingerprint is processed as a transmitted light picture.

Since now in the process of personal identification the surface of the forward area of the finger which bears the dermal ridges rests on the finger resting surface, the dermal ridges in areas "close" the inputs of the fibers of the finger resting surface so that in these areas of the fiber optic finger resting surface closed by the dermal ridges only very little or no so-called passage light which is scattered within the forward area of the finger reaches the finger resting surface.

In the areas of the recesses between the dermal ridges on the other hand more scattered light travels into the fibers of the finger resting surface and accordingly through the finger resting surface to a sensor unit which preferably has at least one photosensitive surface and/or at least one photosensitive layer so that an extremely sensitive instrument is made available for identification of individuals using a fingerprint, especially using the areas of the dermal ridges and using the areas between the dermal ridges.

The recorded optical picture of the fingerprint therefore travels through the fibers of the finger resting surface into the sensor unit which is located downstream of the finger resting surface and is then analyzed and processed by the evaluation unit which is preferably located downstream of the sensor unit. Here the data obtained in the analysis and processing can preferably be collected and stored in at least

one storage unit located downstream of the sensor unit.

In this connection it is important that it is possible to look completely into the device as claimed in the invention and also that the process of personal identification is transparent and reproducible for the individual to be identified, since this individual must place the forward area of his finger in a psychologically favorable manner simply on the finger resting surface, but need not insert his finger into a cavity or into an opening.

Furthermore, as an optional inventive feature of the device, design for detection of life (so-called "life support") should be mentioned, i.e. based on the brightness difference between the areas of the dermal ridges and the areas between the dermal ridges, with this invention it is also possible to observe or check whether the illuminated object, for example the forward area of the finger, is alive, i.e. for example blood is flowing through it and/or it has a pulse. In this connection the device as claimed in the invention can be designed for example by comparison of the results obtained for two different wavelengths for determining the oxygen saturation in the blood of the forward area of the finger.

Also with this invention for example an individual could only be identified as authenticated or authorized when his current pulse rate differs by not more than ten percent from the stored pulse rate, up or down; thus the pulse rate becomes another criterion for personal identification.

These additional biometric data which relate for example to the pulse reduce the error probability of the identification process because they make it possible to distinguish the living finger of the individual to be identified from a previously obtained print of this finger. The existing data about the changes of the transparency of the forward region of the finger make it possible to determine the pulse of the individual to be identified by computer for example in the evaluation unit and to use the transparency curve which has been obtained in this way analogously to an electrocardiogram (EKG) for medical purposes.

Furthermore, with the device as claimed in the invention optical images can also be determined with a degree of sharpness which is so high that even the sweat glands which are arranged differently specific to the individual and which are located in the forward area of the finger can be clearly and definitively recognized so that within the framework of operation of this device there is the possibility of using the sweat glands for individual identification.

According to one advantageous development of this invention the light source is located on the side of the finger resting surface facing the sensor unit. Here it is a sufficient prerequisite for the fact that the light from the light source can be radiated in the direction to the side of the finger resting surface which is intended for resting the forward region of the finger and which faces away from the sensor unit, i.e. the forward region of the finger of the individual to be identified is irradiated from laterally underneath.

Furthermore, the light source can feasibly be spaced laterally away from the sensor unit. This structural separation of the light source and sensor unit is recommended to the extent that to achieve proper operation of the device it should be avoided that light travel directly from the light source into the sensor unit; rather only light is supposed to travel to the sensor unit which operates preferably on a semiconductor basis, especially on a silicon basis, which was scattered beforehand within the forward region of the finger and accordingly bears information about the dermal ridges, i.e. about the fingerprint.

According to one inventive development of this device for personal identification the light from the light source is radiated in laterally to the side of the finger resting surface which is intended for resting the forward area of the finger and which faces away from the sensor unit. This development can be used especially when the light source is located preferably laterally next to or just barely on the side of the finger resting surface facing away from the sensor unit; also the light source in this development can so to speak be located horizontally and can emit the light "flatly" onto the forward region of the finger.

Optionally the light source can be made as a pulsed light source which is designed for emission of pulsed light so that the device as claimed in the invention as a result of the pulsed light which can be exactly metered can for example also be completely battery-operated. In any case a significant reduction of the current which is necessary to operate the device as claimed in the invention can be achieved, because ambient light can be used and the additionally required light can be exactly metered by means of adaptive light control. In this case the pulse duration of the emitted light pulses advantageously varies roughly from almost zero milliseconds to roughly ninety milliseconds.

Corresponding thereto, the device as claimed in the invention can have at least one pulser unit for controlling the light source, the pulser unit feasibly being located between the light source and at least one control element for the sensor unit.

To signal the individual to be identified the respective operating state of the device, according to one preferred embodiment of this invention there is at least one display device for displaying the various operating states of the device. In this case the display device can feasibly have at least one monochrome or polychrome LED display which signals the various operating states of the device (for example green light: "Device is ready for personal identification" or also "Device has properly identified the individual"; red light: "Device is not ready for personal identification" or "Device has not properly identified the individual").

If the intention is to make this invention especially elegant and/or compact in this connection, it is recommended that the display device be integrated into the light source and/or the display device and the light source be made in one unit.

In order for example to enable acquisition of the respective operating state of the device for colorblind individuals, the display device can signal the various operating states of the device according to one advantageous alternative or supplementary embodiment also by at least one blinking and/or pulsing light signal.

According to one especially inventive development of this invention, at least one optical system is located downstream of the light source. One such optical system on the one hand performs a certain protective function, i.e. the optical system prevents the individual who is to be identified by his fingerprint from touching the sensitive and easily damaged light source when the forward region of his finger is placed in position.

But in one especially advantageous manner the optical system is designed to deflect the light radiated from the light source onto the side of the finger resting surface facing away from the sensor unit and/or to uniformly and/or diffusely distribute the light radiated from the light source on the side of the finger resting surface facing away from the sensor unit.

In this way, uniform illumination of the forward area of the finger is ensured, by which an informative optical picture of the fingerprint which originates from the forward region of the finger is formed. This is important for convincing operation of the device as claimed in the invention.

Preferably the optical system is made as at least one filter, at least one lens, as at least one

prism, as at least one optical fiber, as at least one fiber optic element and/or as at least one mirror, the use of the aforementioned optical elements alone or in combination being dependent for example on the available space or on the required degree of illumination.

Both to achieve the above explained protective function and also with respect to the light distribution it is a good idea to choose plastic as the material of the optical system. Plastic is an economical and durable material which has optical properties which are convincing especially when transparent.

To achieve the above explained protective function it can furthermore be feasible if at least the side of the optical system facing away from the light source is coated with at least one material which is transparent to the light of the light source, especially with a material which is transparent to infrared light and/or to visible light. In this way the often sensitive optical system is protected against damage, for example against scratching by vandals and/or against fouling, cleaning of the optical system also being facilitated by coating with the transparent material.

According to one especially inventive development of this invention, on the side of the finger resting surface which is intended for resting the forward area of the finger and which faces away from the sensor unit there is at least one advantageously ergonomically shaped finger guide. This finger guide which can be made for example in the form of a "finger shoe" makes it substantially easier for the user of the device, for example an individual to be identified, to handle the device not only in a psychological, but also in a practical regard since the individual to be identified instinctively recognizes by the arrangement of the finger guide in what position and at what point the forward region of the finger should be placed on the side of the finger resting surface which faces away from the sensor unit to record the fingerprint.

If the device as claimed in this invention is to be developed in an especially clever manner, it is recommended that the optical system be made as a finger guide. In this way the advantages of the finger guide, specifically among others ensuring optimum placement of the forward area of the finger for recording the fingerprint, are feasibly combined with the advantages of the optical system, specifically among others the function as a deflection component for the generated light and the guarantee of clean, uniform illumination of the forward region of the finger which is to be illuminated.

In this connection it must be mentioned especially that by adaptive light control in an especially advantageous manner flexible and uniform transitions for the most varied areas of the composite overall picture can be achieved. Therefore, by the interaction of adaptive light control with the finger guide which is optionally implemented in the optical system, uniform light distribution on the object to be illuminated is guaranteed with the greatest possible contrast.

The stipulations established above with respect to the coating of the optical system with transparent material also apply to one advantageous embodiment of this invention in which at least the side of the finger resting surface facing away from the sensor unit is coated with at least one material which is transparent to the light of the light source, especially with a material which is transparent to infrared light and/or to visible light. In this case one such coating of the finger resting surface can be of inventive importance to the extent that an undamaged, i.e. among others, unscratched and clean finger resting surface is essential for proper operation of this device for personal identification.

Both in the case of the optical system and also in the case of the finger resting surface the material which is transparent to the light of the light source according to one advantageous embodiment is varnish.

With respect to this invention it can be advantageous if the light source is a light emitting diode (LED), the advantage of these light emitting diodes being especially apparent in that they are very small and accordingly are also used in devices according to this invention, in which in the course of miniaturization little space is available. Other pluses are the low weight, durable configuration, low operating voltage and high service life of the light emitting diodes.

According to one preferred development of this invention the light source emits infrared light, and the infrared light can have for example a wavelength of roughly 900 nanometers. The light source which in one feasible embodiment can also emit infrared light of two different wavelengths should have a power of for example roughly 0.1 milliwatt to roughly 5 watts, especially a power of roughly two milliwatts to roughly 100 milliwatts, to prevent unduly high heat-up of the device.

In order to impart a certain stability to this device for personal identification, the sensor unit is feasibly arranged on at least one support unit. This support unit in turn can be located on at least one

circuit board unit.

In order to ensure proper transport of the light which carries the optical image of the fingerprint and which originates from the forward area of the finger through the finger resting surface to the sensor unit, the fibers in the finger resting surface according to one inventive development are located essentially perpendicular to the entry surface and/or to the exit surface of the finger resting surface.

For the same purposes the fibers in the finger resting surface according to one preferred embodiment of this invention are located essentially parallel to one another. Alternatively the fibers in the finger resting surface according to one inventive development can have essentially two directions which are located at an angle to one another. Here an embodiment is preferred in which the fibers in the finger resting surface are arranged in layers, the fibers within one layer being essentially parallel to one another and the fibers of the layers which are adjacent to one another being located at an angle to one another.

In the aforementioned preferred embodiment, the fibers of the finger resting surface which are arranged in one direction at an angle to the other direction are feasibly provided for transport of the light to the side of the finger resting surface facing away from the sensor unit, while the fibers of the finger resting surface which are located in the other direction are intended feasibly for transport of the optical image of the fingerprint to the sensor unit.

In this connection, it must be mentioned in particular that the aforementioned preferred embodiment with two preferred directions for the fibers can make the arrangement of the optical system obsolete in that uniform illumination of the forward area of the finger by the fibers of the finger resting surface located in one direction at an angle to the other direction is ensured.

According to one especially inventive development of this device for personal identification, at least some of the fibers in the finger resting surface are surrounded at least in sections by (light)-absorbing material in the form of a coating and/or in the form of a sleeve. In this way, light which is incident for example from the outside through one side surface of the fibers and/or light which is incident from an adjacent fiber is absorbed so that via each fiber only the light entering the finger resting surface at a certain region is relayed by the finger resting surface to the exit surface thereof. In this way any change of the light pattern which is obtained on the entry surface of the finger resting surface is reliably

prevented.

According to one alternative or supplementary, likewise especially inventive, development of this invention for personal identification at least some of the fibers in the finger resting surface are surrounded at least in sections by (light-)reflecting material in the form of a coating and/or in the form of a sleeve which reflects back the light in the respective fiber preferably again from the wall of this fiber into the interior of this fiber. In this way the transport of the optical image through the finger resting surface to the sensor unit is promoted to the extent that each fiber relays only the light entering the finger resting surface at a certain area through the finger resting surface to the exit surface thereof. In this way any change of the light pattern which is obtained on the entry surface of the finger resting surface is reliably prevented.

Regardless of the aspect of omitting the optical system, for the finger resting surface an extension is feasible which extends into the area above the light source so that the latter is covered and is protected against manual interventions.

Since the sensor unit is of course to be reached by the light which carries the information about the optical image of the fingerprint, i.e. the light which is scattered by the forward region of the finger, it is recommended that at least one opaque blocking layer be provided within the finger resting surface, since this opaque blocking layer prevents the light emitted by the light source from directly, i.e. without scattering in the forward area of the finger, travelling to the sensor unit. The blocking layer can be made here for example the form of closed fibers.

At least one opaque blocking layer which can be provided between the light source and the sensor unit serves the same purposes as the blocking layer within the finger resting surface. In this connection the material of the blocking layer which is opaque to the light of the light source can be varnish, for example.

If this invention for personal identification is to be inventively developed, there is at least one filter which is made preferably as a linear filter in order to absorb stray and excess ambient light and accordingly to reliably preclude oversaturation of the sensor unit.

In other words, this means that the adaptive light control develops its optimum action when the

sensor unit passes into a oversaturated state, not for example by normal daylight, but to a certain extent by itself, and one such oversaturated state can be feasibly prevented by the arrangement of the filter, since due to this filter this device for personal identification can operate even at an illuminance of the ambient light of more than roughly 3000 lux, and a realistic upper boundary should be at an illuminance of the ambient light of roughly 40,000 lux. To do this, the filter feasibly has an absorption factor of roughly 99 percent, i.e. the light-absorbing filter acts as a result as a "dark chamber" (in contrast for example to the filter disclosed in German patent disclosure document DE 44 04 918 A1 with "windows" which do not offer effective protection against oversaturation and also cannot assume the function of a "dark chamber").

The arrangement of the filter within this device for personal identification is determined by the structure, dimensioning and purpose of the device. But it seem feasible

- to arrange the filter between the finger resting surface and the sensor unit; and/or
- to arrange the filter on the side of the finger resting surface facing away from the sensor unit; and/or
- to arrange the filter on the side of the finger resting surface facing the sensor unit; and/or
- to provide the filter within the finger resting surface.

According to one especially advantageous development of this invention, it can be part of the adaptive light control (ALC), i.e. "intelligent light control", to make the absorption factor of the filter variable over the different areas of the optical picture.

The background of this especially advantageous development is the fact that the intensity distribution and accordingly the contrast of the light which has been scattered within the forward area of the finger is neither uniform nor constant over the entire width of the optical picture, but is less in the middle regions of the optical picture than in the edge regions of the optical image; this among others is associated with the fact that there is at least one light source laterally next to the finger resting surface and that the light from the light source can be radiated in the direction to the side of the finger resting surface which is intended for placing the forward area of the finger and which faces away from the sensor unit. In this way less light travels into the central regions which are covered by the forward region of the

finger on the side of the finger resting surface facing away from the sensor unit than into the side regions so that the intensity and, in direct proportion thereto, the contrast of the scattered light in the central regions is weaker than in the side regions.

To eliminate this defect, according to one preferred development of this invention the absorption factor of the filter in the edge regions of the optical picture can be greater and in this case greater for example by roughly a factor of 2 to 3 and/or by roughly six decibels to roughly ten decibels than the absorption factor of the filter in the middle regions of the optical picture.

Therefore, this is an optional inventive measure in which the density of the optical filter is made variable over the different regions of the optical image such that the density in the edge areas of the filter is greater, and for example by roughly a factor of 2 to 3 and/or by roughly six decibels to roughly ten decibels, than the density of the filter in the middle regions of the optical image.

In this way, in an elegant manner which is implemented by optical modulation it is possible to compensate for the fact that the intensity and the contrast of the scattered light in the central regions is weaker than in the side regions, and the absorption factor can be selectively chosen over the different regions of the optical picture such that the output signal which is directly proportional to the quotient of the respective scattered light intensity/contrast and the respective absorption factor is of rather constant intensity; this technical measure makes it possible to significantly improve the quality of the results which can be achieved with this device.

In this connection it should not be overlooked that the above described optional technical measure of optical modulation compared to the optional technical measure of electronic modulation by means of the gain which was described farther above has the further advantage that intensification of disruptive effects, for example electronic noise or the like, is precluded, especially in the middle areas of the optical image during optical modulation; rather these unwanted disruptive influences can be reduced even more by optical modulation.

In order to enable the sensor unit to directly acquire the light signals, which acquisition has not been adulterated by disruptive effects, an embodiment is preferred in which the sensor unit direct borders the finger resting surface and/or in which the sensor unit is attached to the exit surface of the finger

resting surface.

The sensor unit can feasibly have at least one component based on CMOS technology or at least one circuit based on CMOS technology (CMOS = complementary MOS).

Alternatively or in addition, there can be at least one charge-coupled component or at least one charge-coupled circuit (CCD = charge coupled device). Here it can be at least one single-range CCD which acts as a light-sensitive unit and which does not have a special light-protected region.

In this connection one skilled in the art will know how to estimate it as advantageous that in CCD sensor units one semiconductor surface is required which corresponds simply to half of the conventionally required surface, since in CCD sensor units the obtained image can be read out directly in the dark phase and need not, as in conventional sensor units, be transported into a region which is insensitive to light, which takes up generally fifty percent of the sensor area and from which read-out ultimately takes place.

The image is built up and the charges are read out here in a photosensitive unit in integrated form, the process of image build-up and the process of read-out of the charges being indeed separated from one another in time, but not in space, in contrast to the dual-range CCDs. Here the single-range CCDs are characterized among others by the fact that compared to the dual- range CCDs they can be produced much more easily and economically because in the single-range CCDs the number of components for essentially the same dimensions of the photosensitive unit is only half as great as in the dual-range CCDs.

In this connection it must be considered in any case that single-range CCDs with continuous illumination of the object to be illuminated cannot be used since with a simultaneous progression of the image build-up process and the read-out process unwanted mingling of the resulting images would take place.

For this reason, as detailed above, the light source can be made as a pulsed light source which is designed for irradiation of pulsed light. In correspondence thereto the device as claimed in the invention can have at least one pulser unit for controlling the light source, the pulser unit feasibly being located between the light source and at least one control element for the sensor unit.

In this connection one skilled in the art will know how to estimate it as advantageous that the

illumination of the forward region of the finger with light pulses entails a significant reduction of instabilities and nonuniformities in the resulting optical image of the fingerprint and as a result thereof also in the generated electrical signals.

These effects are a direct consequence of the temporarily short light pulses of preferably roughly one millisecond duration, the effect of blood flow in the forward area of the finger to be transilluminated on the quality of the resulting optical image of the fingerprint becoming a negligible quantity.

Furthermore, reducing the image build-up time also decisively reduces the effect of the ambient light conditions on optical imaging of the skin relief.

Accordingly, using the device for personal identification as claimed in the invention makes it possible to obtain clear and sharp optical images of the fingerprint instead of blurry optical images which are formed when using continuous illumination and an exposure time which corresponds to the image lead time, in which all the information about the interior and/or about the surface of the forward region of the finger at a certain time is contained.

This improvement of quality of the obtained images makes it possible to significantly reduce the frequency and probability of errors in personal identification. Here it is now possible to further increase by image sequence processing the information content of the dactyloscopic images as a result of obtaining additional biometric data, for example, the particulars of the pulse of the individual to be identified and thus to further improve the security of personal identification.

The use of pulsed light sources leads not only to the above described major improvement of image quality, but also makes it possible to use at least one camera with single-range CCDs as photosensitive units. The use of single-range CCDs makes it possible to obtain high quality images of larger areas. This enlargement of the areas together with the improvement of the stability of the optical images leads to a further reduction of the error probability in personal identification.

Here the production of single-range CCDs with a diagonal of the light-sensitive area of for example roughly 16 millimeters to for example roughly 24 millimeters and with a fiber optic input is a technically rather simple task, which makes it possible to produce relatively simple and economical devices for personal identification. Furthermore, in devices as claimed in the invention with single-range

CCDs less distortion of information occurs than in devices with other types of charge displacement.

The use of single range CCDs in devices which operate with continuous illumination is not possible because the continuous light is incident on the CCDs not only during the image build-up phase, but also during the read-out phase and therefore intermingling of charges would occur; this would make it impossible to obtain clear optical images of the skin relief of the forward region of the finger.

Other embodiments, features and advantages of this invention are described below in the drawings using Figures 1 to 4C, by which in exemplary form three embodiments of the device for personal identification as claimed in the invention are illustrated.

Figure 1 shows a first embodiment of a device for personal identification as claimed in the invention;

Figure 2 shows a second embodiment of a device for personal identification as claimed in the invention;

Figure 3A shows a third embodiment of a device for personal identification as claimed in the invention;

Figure 3B shows an extract from the finger resting surface of the device for personal identification from Figure 3A;

Figure 3C shows an extract from the finger resting surface from Figure 3B in a partial vertical section;

Figure 4A shows a diagram in which the contrast of the light scattered within the forward region of the finger is plotted schematically over the width of the optical image;

Figure 4B shows a diagram in which the amplification of the electrical signals which was chosen in the device for personal identification from Figure 1 is plotted schematically over the width of the optical image; and

Figure 4C shows a diagram in which the absorption which was chosen in the device for personal identification from Figure 1 is plotted schematically over the width of the optical image.

The same or similar components or features of the invention are provided with identical reference numbers in Figures 1 to 4C.

The three embodiments of a device for personal identification by means of a fingerprint shown in Figures 1 to 3A are used to record and process fingerprints and can be used in any regions in which personal identification is necessary. For example, in this connection the areas of computer engineering, entry systems, criminal science, medicine, protective systems in general and the banking and financial sector can be named.

Here the three embodiments of the device for personal identification by means of a fingerprint shown in Figures 1 to 3A are characterized in that on the one hand illumination of the forward area of the finger which leads to sufficient, reliable results is possible, but on the other hand it is possible to look completely into the device for personal identification itself and also the process of personal identification is transparent and reproducible for the individual to be identified.

This is done by the three embodiments of a device for personal identification by means of a fingerprint shown in Figures 1 to 3A each having four light sources 10 located symmetrically to the sensor unit 40 for illuminating the forward region of a finger (of these four light sources 10, in Figures 1 to 3A for reasons of clarity only two at a time are shown) and a fiber optical finger resting surface 30 for taking an optical picture of the fingerprint.

The optical image of the fingerprint is transported through the finger resting surface 30 to a sensor unit 40 in which the optical image of the fingerprint is converted into electrical signals. The sensor unit 40 is located on a carrier unit 50 which in turn is located on a circuit board unit 60.

At this point it is decisive that the light sources 10 are located laterally next to the finger resting surface 30 and that the light from the light sources 10 can be radiated in the direction to the side of the finger resting surface 30 which is intended for resting the forward area of the finger and which faces away from the sensor unit 40.

Light incidence on the forward area of the finger takes place essentially from the side, at least some of the light penetrating into the interior of the forward area of the finger and being scattered there, the scattering taking place essentially into all directions, thus among others also in the direction of the fiber optic finger resting surface 30; therefore the invention shown in Figures 1 to 4C is based to a certain extent on transmitted light technology, i.e. the optical image of the fingerprint is processed as a

transmitted light picture.

Since now in the process of personal identification the surface of the forward area of the finger which bears the dermal ridges rests on the finger resting surface 30, the dermal ridges in areas "close" the inputs of the fibers 310 (compare Figures 3B and 3C) of the finger resting surface 30 so that in these areas of the fiber optic finger resting surface 30 which are closed by the dermal ridges only very little or no so-called passage light which is scattered within the forward area of the finger reaches the finger resting surface 30.

In the areas of the recesses between the dermal ridges on the other hand more scattered light travels into the fibers 310 of the finger resting surface 30 and accordingly through the finger resting surface 30 to a sensor unit 40 so that an extremely sensitive instrument is made available for identification of individuals using a fingerprint, especially using the areas of the dermal ridges and using the areas between the dermal ridges.

The fibers 310 in the finger resting surface 30 are surrounded by (light-)reflecting material in the form of a coating which reflects back the light in the respective fiber 310 again from the wall of this fiber 310 into the interior of this fiber 310. In this way, transport of the optical image through the finger resting surface 30 to the sensor unit 40 is promoted to the extent that each fiber 310 relays only the light entering the finger resting surface 30 at a certain area through the finger resting surface 30 to the exit surface thereof. In this way any change of the light pattern which is obtained on the entry surface of the finger resting surface 30 is prevented.

The optical picture of the fingerprint which has been recorded in this way therefore travels through the fibers 310 of the finger resting surface 30 into the sensor unit 40 which is located downstream of the finger resting surface 30 and is then analyzed and processed by the evaluation unit which is preferably located downstream of the sensor unit 40.

Based on the brightness differences between the areas of the dermal ridges and the areas between the dermal ridges, with the invention shown in Figures 1 to 4C it is also possible to observe or check whether the illuminated object, for example the forward area of the finger, is alive, i.e. for example blood is flowing through it and/or it has a pulse (so-called life support).

Thus, with the invention shown in Figures 1 to 4C for example an individual can only be identified as authenticated or authorized when his current pulse rate differs by not more than ten percent from the stored pulse rate, up or down; thus the pulse rate becomes another criterion for personal identification.

These additional biometric data which relate for example to the pulse reduce the error probability of the identification process because they make it possible to distinguish the living finger of the individual to be identified from a previously obtained print of this finger. The existing data about the changes of the transparency of the forward region of the finger make it possible to determine the pulse of the individual to be identified by computer and to use the transparency curve which has been obtained in this way analogously to an electrocardiogram (EKG) for medical purposes.

Furthermore, with the device as shown in Figures 1 to 3A optical images can also be determined with a degree of sharpness which is so high that even the sweat glands which are arranged differently specific to the individual and which are located in the forward area of the finger can be clearly and definitively recognized, so that within the framework of operation of the device shown in Figures 1 to 3A there is the possibility of using the sweat glands for individual identification.

It is possible to look completely into the device as claimed in the invention which is shown by way of example in Figures 1 to 3A, and the process of personal identification is transparent and reproducible for the individual to be identified, since this individual must place the forward area of his finger in a psychologically favorable manner simply on the finger resting surface 30, but need not insert his finger into a cavity or into an opening.

The invention illustrated using the three embodiments shown in Figures 1 to 3A is characterized at this point in that the duration and the intensity of the light pulses emitted by the light sources 10 can be controlled depending on the ambient light conditions, i. e. adaptive light control (ALC), therefore a type of "intelligent light control", is made available, by which the deficiencies of changing ambient light conditions, as for example changing room illumination or changing incident solar radiation, can be compensated by the three embodiments of the device shown in Figures 1 to 3A or the algorithm which controls the device being adapted to the respective light conditions.

To do this, in the three sample devices for personal identification shown in Figures 1 to 3A there

is one control means 40, 70 each for controlling the duration and the intensity of the light pulses. With this control means 40, 70 which is made as a digital signal processor (DSP) with a microcontroller, a continuous or temporary measurement process can be carried out with which permanently good image quality can be determined and with which if necessary optimum saturation matched to contrast and depth of sharpness by means of brief light pulses can be achieved, the brief light pulses in their duration and in their intensity being metered exactly to the actually required amount of light.

The control means 40, 70 has an acquisition module 40 for acquiring the ambient light conditions, the acquisition module 40 in the three embodiments in Figures 1 to 3A being made integral with the sensor unit 40.

An evaluation module 70a for determining the duration and/or the intensity of the light pulses matched to the ambient light conditions acquired by the acquisition module 40 is series connected to the acquisition module 40, the evaluation module 70a being made integrally with the evaluation unit 70a which is located downstream of the sensor unit 40 and which will be detailed below.

Likewise, one storage module 70b at a time for storing threshold values which have been determined for controlling the duration and the intensity of the light pulses is series connected to the acquisition module 40, the storage module 70b being made integrally with at least one storage unit 70b which is located downstream of the sensor unit and which will be detailed below.

If at this point the acquisition module 40 has acquired the respective ambient light conditions, they are analyzed and evaluated in the evaluation module 70a, comparison with the stipulated threshold values which have been stored in the storage module 70b taking place in the evaluation module 70a.

Depending on the result of this comparison, the light sources 10 which are connected to the control means 40, 70 and here especially to the evaluation module 70a, are operated by the control means 40, 70, the duration and the intensity of the light pulses which have been emitted by the light sources 10 being adapted to the determined ambient light conditions.

In this way, the light pulses can be made dynamic and adaptive both in their duration and also in their intensity in order to make available for any type of ambient light (for example, strong incident solar radiation, weak incident solar radiation, dimmed light, diffuse light, gas light, moonlight, artificial

illumination...) the required incident light radiation and therefore to obtain a high-contrast and defined picture of the fingerprint.

In particular, with adaptive light control illuminances of zero lux to roughly 40,000 lux can be accomplished, the latter illuminance value corresponding roughly to direct incident solar radiation. The results which can be achieved with this adaptive light control, compared to conventional illumination systems with continuous light, have an increase in contrast depth and depth of focus by up to roughly eighty percent, the type of light control shown by way of example in Figures 1 to 3A having the advantage that under changing illumination conditions it makes available and can meter the required amount of light in a time interval of less than one hundred milliseconds so that under all conceivable light conditions an almost uniform picture quality can be achieved.

Therefore, the decisive advantage of this device shown by way of example in Figures 1 to 3A can be seen in the "intelligent triggering" which if necessary adjusts the incident amount of light to a certain extent itself and makes it available and computes it around the object to be illuminated, i.e. around the forward area of a finger, for each region separately, so that overexposure or underexposure in the device for personal identification as shown in Figures 1 to 3A is precluded with a probability which borders on certainty.

In addition, the invention shown in Figures 1 to 4C enables uniform illumination of an object, for example the forward area of a finger, regardless of the thickness of the object which otherwise can have more or less strong light conductivity or a more or less strong reflectivity, and regardless of whether this object is illuminated frontally, laterally, and/or on the back side by stray light.

Accordingly, it is also irrelevant at what angle and from where light is radiated onto the object to be illuminated; only the duration and/or the intensity of the additionally required light need be controlled individually for each region. The advantages of this adaptive light control ultimately lead to the fact that a finger image can be determined without significantly changing the exposure times while maintaining contrast and depth of focus to the full extent.

As already cited above, the control means 40, 70 which is intended for implementing adaptive light control in Figures 1 to 3A has at least one acquisition module 40, an evaluation module 70a and a

storage module 70b. If at this point the acquisition module 40 is made integrally with the sensor unit 40 (compare Figures 1 to 3A), the photosensitive surface of the sensor unit 40 can request the required amount of light by means of adaptive light control to a certain extent itself, and for each of its regions; this works preferably since the evaluation module 70a of the control means 40, 70 is made integrally with the evaluation unit 70a.

Therefore the adaptive light control is able to compute and immediately deliver, for each region of the surface of the sensor unit 40, the amount of light necessary in view of the ambient light conditions with respect to duration and with respect to the intensity in the evaluation module 70a with regard to the optimum saturation.

With respect to the effects of adaptive light control, in the three embodiments of this invention which are shown in Figures 1 to 3A, it is of substantial importance that there is at least one filter 90 which is made as a linear filter in order to absorb stray and excess ambient light and accordingly to reliably preclude oversaturation of the sensor unit 40.

In other words, this means that the adaptive light control develops its optimum action in Figures 1 to 3A when the sensor unit 40 passes into an oversaturated state, not for example by normal daylight, but to a certain extent "by itself", one such oversaturated state being prevented by the arrangement of the filter 90, since due to this filter 90 the device exemplified in Figures 1 to 3A for personal identification can operate even at an illuminance of the ambient light of more than roughly 3000 lux, and a realistic upper boundary should be at an illuminance of the ambient light of roughly 40,000 lux. To do this, the filter 90 feasibly has an absorption factor of roughly 99 percent, i.e. the light-absorbing filter acts as a result as a "dark chamber".

The arrangement of the filter 90 within the respective device for personal identification is determined by the structure, dimensioning and purpose of the device. Thus

- in the first embodiment (compare Figure 1) the filter 90 is located between the finger resting surface 30 and the sensor unit 40;
- in the second embodiment (compare Figure 2) the filter 90 is located on the side of the finger resting surface 30 facing the sensor unit 40 and within the finger resting surface 30; and

- in the third embodiment (compare Figure 3) the filter 90 is located on the side of the finger resting surface 30 facing away from the sensor unit 40.

As already indicated, the light sources 10 (compare Figures 1 to 3A) in adaptive light control perform an important function within the framework of this invention. Here it must be considered that for purposes of uniform illumination of the forward area of the finger, in the three embodiments shown in Figures 1 to 3A there is more than one light source (in the three embodiments of Figures 1 to 3A four light sources at a time) which are arranged symmetrically to one another and which are arranged distributed annularly, here especially essentially uniformly, around the finger resting surface 30.

The respective duration and the respective intensity of the light pulses emitted by the respective light source 10 can be selectively controlled as matched to the ambient light conditions in the three embodiments of Figures 1 to 3A; this means in other words that the respective duration and the respective intensity of the light pulses emitted by the individual light sources 10 can be controlled independently of one another, in this case especially depending on given threshold values. Therefore all light sources 10 can be triggered independently of one another, the respective duration and the respective intensity being computed preferably individually in the evaluation module 70a for each light source 10.

The evaluation unit 70a and the storage unit 70b have already been mentioned. They are located

- in the first embodiment (compare Figure 1) in a structural unit as the control means 70 which is connected to the light sources 10 and via the carrier unit 50 and via the circuit board unit 60 to the sensor unit 40;
- in the second embodiment (compare Figure 2) in structural separation as the control means 70 which is connected to the light sources 10 via the circuit board unit 60 and via the carrier unit 50 and via the circuit board unit 60 to the sensor unit 40; and
- in the third embodiment (compare Figure 3) structurally and functionally integrated into the circuit board unit 60.

As accordingly follows from Figures 1 to 3A, the evaluation unit 70a is located downstream of the sensor unit 40 and is designed to analyze and process the recorded optical picture of the fingerprint

which travels through the fibers 310 of the finger resting surface 30 into the sensor unit 40 which is located downstream of the finger resting surface 30. Here the data obtained in the analysis and processing can be collected and stored in a storage unit 70b which is likewise located downstream of the sensor unit 40.

The storage unit 70b furthermore stores the data, especially the fingerprint data of the individual to be identified, and the data computed in the identification process from the current optical image of the fingerprint in the evaluation unit 70a can be referenced to the data stored in the storage unit 70b and can be adjusted with them.

If this comparison results in agreement, the individual using the device is considered identified, authenticated or also authorized so that for example access is allowed; in the absence of agreement on the other hand the individual using the device is considered not identified, not authenticated or not authorized so that for example access is denied.

In the first two embodiments of this invention shown in Figures 1 and 2 one plastic optical system 20 which is made as a lens is located downstream of each of the light sources 10. This optical system 20 on the one hand performs a certain protective function, i.e. the optical system 20 prevents the individual who is to be identified by his fingerprint from touching the sensitive and easily damaged light source 10 when the forward region of his finger is placed in position.

But in particular the optical system 20 is designed to deflect the light radiated from the light sources 10 onto the side of the finger resting surface 30 facing away from the sensor unit 40 and to diffusely distribute the light radiated from the light sources 10 on the side of the finger resting surface 30 facing away from the sensor unit 40.

In this way, uniform illumination of the forward area of the finger is ensured, by which an informative optical picture of the fingerprint which originates from the forward region of the finger is formed. This is important for convincing operation of the device as claimed in the invention.

The first two embodiments of this invention shown in Figures 1 and 2 in this connection are characterized in that the optical system 20 is made as an ergonomically shaped finger guide. Therefore, on the side of the finger resting surface 30 which is intended for resting the forward area of the finger and

which faces away from the sensor unit 40 there is a finger guide which is made in the form of a finger receiver and which makes it substantially easier for the user of the device, for example an individual to be identified, to handle the device not only in a psychological, but also in a practical regard, since the individual to be identified instinctively recognizes by the arrangement of the finger guide in what position and at what point the forward area of the finger should be placed on the side of the finger resting surface 30 which faces away from the sensor unit 40 to record the fingerprint (compare Figures 1 and 2).

In this way, in the first two embodiments of this invention shown in Figures 1 and 2, the advantages of the finger guide, specifically among others ensuring optimum placement of the forward area of the finger for recording the fingerprint, are combined with the advantages of the optical system 20, specifically among others the function as a deflection component for the generated light and the guarantee of clean, uniform illumination of the forward region of the finger which is to be illuminated.

In this connection, it must be mentioned especially that by adaptive light control flexible and uniform transitions for the most varied areas of the composite overall picture can be reached. Therefore, by the interaction of adaptive light control with the finger guide which is implemented in the optical system 20 (compare Figures 1 and 2) uniform light distribution on the object to be illuminated is guaranteed with the greatest possible contrast.

In the first embodiment of this invention shown in Figure 1, the side of the optical system 20 facing away from the light source 10 is coated with a material which is transparent to the light of the light sources 10, i.e. with a material 80 which is transparent to infrared light. In this way the often sensitive optical system 20 is protected against damage, for example against scratching by vandals and/or against fouling, cleaning of the optical system 20 also being facilitated by coating with the transparent material 80.

In the same way, in the first embodiment of this invention which is shown in Figure 1, the side of the finger resting surface 30 facing away from the sensor unit 40 is coated with a material 10 which is transparent to the light of the light sources 10, i.e. with a material 10 which is transparent to infrared light. In this case one such coating or the finger resting surface 30 can be of great importance to the extent that an undamaged, i.e. among others, unscratched and clean finger resting surface 30 is essential for proper operation of this device for personal identification which is shown in Figure 1.

Both in the case of the optical system 20 and also in the case of the finger resting surface 30 the material 80 which is transparent to the light of the light sources 10 is varnish.

With respect to the first embodiment of this invention which is shown in Figure 1, it must furthermore be mentioned especially that it is part of the adaptive light control (ALC), i.e. "intelligent light control", to make the amplification of the electrical signals in the sensor unit 40 or in the evaluation unit 70a variable over the different regions x (compare Figures 4A and 4B) of the optical picture.

The background of this is the fact that the intensity distribution and accordingly the contrast of the light which has been scattered within the forward area of the finger is neither uniform nor constant over the entire width x of the optical picture, but is less in the middle regions of the optical picture than in its edge regions (compare the diagram in Figure 4A, in which the contrast of the light which has been scattered within the forward area of the finger is plotted schematically over the width x of the optical image); this among others is associated with the fact that there are light sources laterally next to the finger resting surface 30 and that the light from the light sources 10 can be radiated in the direction to the side of the finger resting surface 30 which is intended for placing the forward area of the finger and which faces away from the sensor unit 40. In this way less light travels into the central regions which are covered by the forward region of the finger on the side of the finger resting surface 30 facing away from the sensor unit 40 than into the side regions so that the intensity and, in direct proportion thereto, the contrast of the scattered light in the central regions is weaker than in the side regions.

To eliminate this defect, in the first embodiment of this invention which is shown in Figure 1 the amplification of the electrical signals in the middle regions of the optical picture is greater by a factor of roughly 2 to 3 than the amplification of the electrical signals in the edge regions of the optical picture (compare the diagram in Figure 4B in which the amplification of the electrical signals chosen in the device for personal identification from Figure 1 is schematically plotted over the width x of the optical image).

This electronic modulation by means of variable gains is done in each line of the optical picture.

In this way, in an electronically implemented manner it is possible to compensate for the fact that the intensity and the contrast of the scattered light in the central regions is weaker than in the side regions (compare Figure 4A), and the amplification can be selectively chosen over the different regions x of the

optical picture such that the output signal which is directly proportional to the product of the respective scattered light intensity/contrast (compare Figure 4A) and the respective gain (compare Figure 4B) is of rather constant intensity; this technical measure significantly improves the quality of the results which can be achieved with the first embodiment which is shown in Figure 1.

The second embodiment shown in Figure 2 differs from the first embodiment shown in Figure 1 not only in that a material which is transparent to the light of the light sources 10 is applied either to the optical system 20 or to the finger resting surface 30, but mainly in that the light sources 10 are located on the side of the finger resting surface 30 facing the sensor unit 40, i.e. are located in Figure 2 underneath the finger resting surface 30.

In this case there is the sufficient prerequisite for the fact that the light from the light sources 10 is radiated in the direction to the side of the finger resting surface 30 which is intended for resting the forward region of the finger and which faces away from the sensor unit 40, i.e. the forward region of the finger of the individual to be identified is irradiated from laterally underneath.

With respect to the second embodiment of this invention which is shown in Figure 2, it must furthermore be mentioned especially that it is part of the adaptive light control (ALC), i.e. "intelligent light control", to make the absorption factor of the filter 90 variable over the different regions x (compare Figures 4A and 4C) of the optical picture.

The background of this is the fact that the intensity distribution and accordingly the contrast of the light which has been scattered within the forward area of the finger is neither uniform nor constant over the entire width x of the optical picture, but is less in the middle regions of the optical picture than in its edge regions (compare the diagram in Figure 4A, in which the contrast of the light which has been scattered within the forward area of the finger is plotted schematically over the width x of the optical image); this among others is associated with the fact that there are light sources 10 laterally next to the finger resting surface 30 and that the light from the light sources 10 can be radiated in the direction to the side of the finger resting surface 30 which is intended for placing the forward area of the finger and which faces away from the sensor unit 40. In this way less light travels into the central regions which are covered by the forward region of the finger on the side of the finger resting surface 30 facing away from

the sensor unit 40 than into the side regions so that the intensity and, in direct proportion thereto, the contrast of the scattered light in the central regions is weaker than in the side regions.

To eliminate this defect, in the second embodiment of this invention which is shown in Figure 2 the density of the optical filter 90 and accordingly the absorption factor in the edge areas of the optical image are greater by roughly a factor of 2 to 3 or by roughly six decibels to roughly ten decibels than the absorption factor of the filter 90 in the middle regions of the optical image. (Compare the diagram in Figure 4C in which the absorption of the filter 90 chosen in the device for personal identification from Figure 2 is schematically plotted over the width x of the optical image).

In this way, in a manner implemented by optical modulation it is possible to compensate for the fact that the intensity and the contrast of the scattered light in the central regions is weaker than in the side regions (compare Figure 4A), and the absorption factor can be selectively chosen over the different regions x of the optical picture such that the output signal which is directly proportional to the quotient of the respective scattered light intensity/contrast (compare Figure 4A) and the respective absorption factor (compare Figure 4C) is of rather constant intensity; this technical measure significantly improves the quality of the results which can be achieved with the second embodiment which is shown in Figure 2.

Furthermore, in the three embodiments of this invention which are shown in Figures 1 to 3A the light sources 10 are spaced laterally away from the sensor unit 40. This structural separation of the light sources 10 and sensor unit 40 is advantageous to the extent that to achieve proper operation of the device light should be prevented from travelling directly from the light source 10 into the sensor unit 40; rather only light is supposed to travel to the sensor unit 40 which was scattered beforehand within the forward region of the finger and accordingly bears information about the dermal ridges, i.e. about the fingerprint.

The first two embodiments shown in Figures 1 and 2 differ from the third embodiment shown in Figure 3 essentially in that in order to ensure proper transport of the light which carries the optical image of the fingerprint and which originates from the forward area of the finger through the finger resting surface 30 to the sensor unit 40, the fibers 310 in the finger resting surface 30 are arranged essentially parallel to one another.

Alternatively the fibers 310, 320 in the finger resting surface 30 of the third embodiment (compare Figures 3A, 3B, and 3C) have essentially two directions which are located at an angle of roughly 45 degrees to one another. Here the fibers 310, 320 in the finger resting surface 30 are arranged in layers, i.e. the fibers 310, 320 within one layer are essentially parallel to one another and the fibers 310, 320 of the layers which are adjacent to one another are located at an angle of roughly 45 degrees to one another.

In the third embodiment (compare Figures 3A, 3B and 3C) the fibers 320 of the finger resting surface 30 which are arranged in one direction at an angle of roughly 45 degrees to the other direction are feasibly provided for transport of the light of the light source 10 to the side of the finger resting surface 30 facing away from the sensor unit 40, while the fibers 310 of the finger resting surface 30 which are located in the other direction are intended for transport of the optical image of the fingerprint to the sensor unit 40.

In this connection it must be mentioned in particular that the embodiment with two preferred directions for the fibers 310, 320 which is illustrated in Figures 3A, 3B and 3C can make the arrangement of the optical system 20 as shown in Figures 1 and 2 obsolete in that uniform illumination of the forward area of the finger by the fibers 320 of the finger resting surface 30 which are located in one direction at an angle of roughly 45 degrees to the other direction is ensured.

Regardless of the aspect of omitting the optical system 20, for the finger resting surface 30 an extension is feasible which extends into the area above the light source 10 so that the latter is covered and is protected against manual interventions (compare Figures 2 and 3).

Since the sensor unit 40 is of course to be reached only by the light which carries the information about the optical image of the fingerprint, i.e. the light which is scattered by the forward region of the finger, in the second embodiment of this invention which is shown in Figure 2 there are two blocking layers 130 within the finger resting surface 30, which are opaque to the light of the light sources 10. These blocking layers 130 prevent the light emitted by the light sources 10 from directly, i.e. without scattering in the forward area of the finger, travelling to the sensor unit 40.

Two blocking layers 140 which in the three embodiments of this invention shown in Figures 1 to

3A are provided between the light source 10 and the sensor unit 40 and which are likewise opaque to the light of the light sources 10 serve the same purposes as the blocking layers 130 within the finger resting surface 30 (compare Figure 2).

Nor should it remain unmentioned that also in the third embodiment of this invention shown in Figure 3A (comparable to the first embodiment of this invention shown in Figure 1) the side of the finger resting surface facing away from the light sources 10 is coated with a material 80 which is transparent to the light of the light sources 10, i.e. with a material which is transparent to infrared light, for example with clear varnish. In this way the often sensitive optical system 30 is protected against damage, for example against scratching by vandals and/or against fouling, cleaning of the finger resting surface 30 also being facilitated by coating with the transparent material 80.

Furthermore, the third embodiment of this invention shown in Figure 3A has a display means 65 for displaying the various operating states of the device. To signal to the individual to be identified the respective operating state of the device, the display means 65 is provided with a LED display which enables even colorblind individuals to acquire the respective operating state of the device by a correspondingly blinking light signal.

Finally, the device according to the third embodiment of Figure 3A is also designed to pass into a neutral state (= so-called "sleep" mode); this creates saving potentials with respect to the power consumption of the device. To do this, there is a capacitive circuit 75 which is integrated into the control means 40, 70, by which circuit the device as shown in Figure 3A after a stipulated time interval of non-use passes into the "sleep" mode and by means of which the device as shown in Figure 3A is re-"awakened" when the forward area of the finger is placed on the finger resting surface 30, i.e. passes again into a ready-to-operate state; viewed in this way, in this device for personal identification both a "sleep" function and also a wake-up function is implemented.